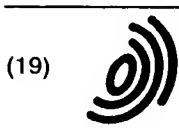


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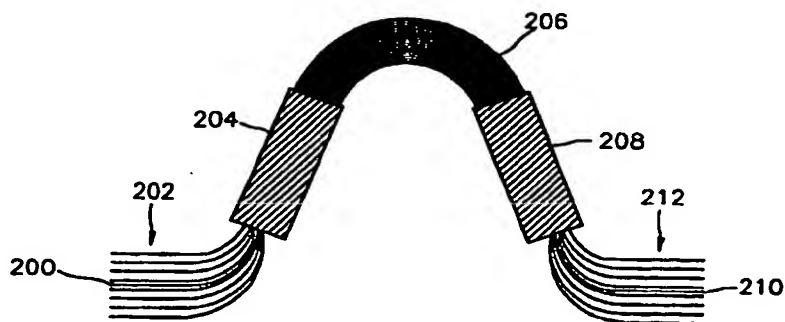
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(54) BIDIRECTIONAL OPTICAL WAVELENGTH MULTIPLEXER/DIVIDER

(57) A bidirectional optical wavelength multiplexer/demultiplexer capable of simultaneously performing light multiplexing and demultiplexing is provided. This optical wavelength multiplexer/demultiplexer includes an optical waveguide array having a plurality of optical waveguides, a planar waveguide region connected to the optical waveguide array, and an arrayed waveguide grating connected to the planar waveguide region. In this device, the optical waveguide array further includes a central waveguide formed at a location on which light transmitted from the arrayed waveguide grating to the planar waveguide region is focused, on the interface between the optical waveguide array and

the planar waveguide region, and light multiplexed with a plurality of wavelengths is received or output via the central waveguide. Accordingly, a central waveguide, through which multiplexed light is received and output, is added at a place where a plurality of optical waveguides and the output spectrum of these waveguides are not affected, so that the wavelength of multiplexed light can be demultiplexed in a direction from an optical waveguide array on one side to an optical waveguide array on the other side, and simultaneously demultiplexed light can be multiplexed in a direction opposite to the above direction.

FIG. 2



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Description

Technical Field

- 5 [0001] The present invention relates to a bidirectional optical wavelength multiplexer and demultiplexer, and a bidirectional optical wavelength multiplexer and demultiplexer which multiplexes and demultiplexes light.

Background Art

- 10 [0002] General optical wavelength multiplexer/demultiplexers using an arrayed waveguide grating (hereinafter, referred to as AWG), which essentially apply the principle of Mach-Zehnder Interferometer, multiplex and demultiplex light using the phase difference.

- [0003] FIG. 1 is a structure view of a conventional optical wavelength multiplexer and demultiplexer. Referring to FIG. 1, a conventional optical wavelength multiplexer and demultiplexer includes N first arrayed waveguides 100 connected to an optical fiber for receiving light having different wavelengths, a first planar waveguide region (free space region, slab waveguide, or star coupler) 102 for distributing received light, an AWG 104 for allowing light from the first planar waveguide region 102 to have different phase differences, a second planar waveguide region 106 in which the light having different phase differences output from the AWG 104 interfere with each other and land at different locations on the opposite side according to wavelength, and M second arrayed waveguides 108 for outputting the light split according to wavelength.

- [0004] This operation of the optical wavelength multiplexer/demultiplexer can be explained in a grating equation which describes the dispersion characteristics of an AWG which acts as a diffraction grating with respect to incident light.

- [0005] In the grating equation, the phase changes caused in the first planar waveguide region 102, the AWG 104 and the second planar waveguide region 106 are all summed, and the sum of the phase changes satisfies the condition in which interference occurs at the interface between the second planar waveguide region 106 and the second arrayed waveguides 108. The grating equation is expressed with respect to light received via an input waveguide, as in Equation 1:

$$n_s d \sin \theta + n_c \Delta L = m \lambda \quad \dots(1)$$

- 35 wherein n_s denotes the effective refractive index of a planar waveguide region, n_c denotes the effective refractive index of an AWG, d denotes the pitch of an AWG, m denotes the diffraction order, ΔL denotes the length difference between adjacent AWGs, and λ denotes the wavelength of the incident light.

- [0006] A central operating frequency λ_0 is the wavelength when θ is zero, and is defined as in Equation 2:

$$n_c \Delta L = m \lambda_0 \quad \dots(2)$$

- 45 [0007] Equation 3, which describes a variation in angular dispersion, that is, a variation in the diffraction angle of light with respect to a change in wavelength, can be obtained from Equation 1:

$$\frac{d\theta}{d\lambda} = \frac{m}{n_s d} \quad \dots(3)$$

- 55 [0008] That is, light beams having different wavelengths land at different angles on the second planar waveguide region of an optical wavelength multiplexer/demultiplexer, according to Equation 3. Thus, an output waveguide is connected at a location corresponding to the diffraction angle of light having a wavelength used in the second planar

waveguide region, and thus performs optical wavelength demultiplexing with respect to the wavelength.

[0009] A general optical wavelength multiplexer/demultiplexer using the structure of an AWG has a structure in which the left side and the right side are symmetrical to each other, so that the same function is performed independently of the direction of connection of the device. Also, in the general optical wavelength multiplexer/demultiplexer having a symmetrical structure, input and output waveguides have no difference in structure, so that an arrayed waveguide can act as an input waveguide or an output waveguide according to the direction of connection.

[0010] This optical wavelength multiplexer/demultiplexer can only operate in one direction at one time, so that there is a method for allowing the optical wavelength multiplexer/demultiplexer to operate having different channel intervals according to the state of connection of the device by differentiating the intervals between first and second arrayed optical waveguides. However, this method is also the same as the conventional method in that an arrayed waveguide acts as an input or output waveguide according to the direction of connection of the device.

[0011] Also, when this optical wavelength multiplexer/demultiplexer is applied to a real system, it is commonly installed and used in only one direction. Therefore, the manufacture of an optical wavelength multiplexer/demultiplexer which can operate with the same operation characteristics in two directions cannot be a necessary condition for designing an optimized device that satisfies a given specification.

Disclosure of the Invention

[0012] An objective of the present invention is to provide a bidirectional optical wavelength multiplexer/demultiplexer which can simultaneously multiplex and demultiplex light by connecting a central waveguide at the interface between each planar waveguide region and an arrayed optical waveguide.

[0013] To achieve the above objective, the present invention provides an optical wavelength multiplexer/demultiplexer including an optical waveguide array having a plurality of optical waveguides, a planar waveguide region connected to the optical waveguide array, and an arrayed waveguide grating connected to the planar waveguide region, wherein the optical waveguide array further includes a central waveguide formed at a location on which light transmitted from the arrayed waveguide grating to the planar waveguide region is focused, on the interface between the optical waveguide array and the planar waveguide region, and light multiplexed with a plurality of wavelengths is received or output via the central waveguide.

Brief Description of the Drawings

[0014]

FIG. 1 is a structure view of a conventional optical wavelength multiplexer/demultiplexer;

FIG. 2 is a structure view of a bidirectional optical wavelength multiplexer/demultiplexer according to the present invention;

FIG. 3 shows the central waveguide of FIG. 2;

FIG. 4 shows a bidirectional optical wavelength demultiplexer using FIG. 2;

FIG. 5 shows a bidirectional optical wavelength multiplexer using FIG. 2; and

FIG. 6 shows a bidirectional optical wavelength multiplexer/demultiplexer using FIG. 2.

Best mode for carrying out the Invention

[0015] Referring to FIG. 2, an optical wavelength multiplexer/demultiplexer according to the present invention includes a first waveguide array 202 having a first central waveguide 200, a first planar waveguide region 204, an arrayed waveguide grating (AWG) 206, a second planar waveguide region 208, and a second waveguide array 212 having a second central waveguide 210. Here, the first central waveguide 200 is formed at the focus (F1) on the interface between the first waveguide array 202 and the first planar waveguide region 204. The focus F1 is a location on the first planar waveguide region 204 where light from the AWG 206 is focused. The second central waveguide 210 is formed at the focus (F2) on the interface between the second planar waveguide region 208 and the second waveguide array 212. The focus F2 is a location on the second planar waveguide region 208 where light from the AWG 206 is focused.

[0016] FIG. 3 shows the relationship between the central waveguide and the planar waveguide region of FIG. 2. Here, reference numeral 300 is an AWG, reference numeral 304 is a planar waveguide region, reference numeral 306 is an optical waveguide array having 8 waveguides, reference numeral 308 is a central waveguide formed at the focus F2, and reference numeral 302 denotes the interface between the AWG 300 and the planar waveguide region 304.

[0017] The interval between optical waveguides connected to a planar waveguide region denotes the interval of the wavelengths of an output spectrum. The central waveguide, which is the feature of the present invention, must be connected to a location that is independent of the locations corresponding to the wavelengths of light transmitted by a plu-

ality of optical waveguides that perform a general multiplexing/demultiplexing function. Here, the central waveguide is connected to the substantial focus on a planar waveguide region.

[0018] FIG. 4 illustrates an example in which a bidirectional optical wavelength multiplexer/demultiplexer according to the present invention operates as a bidirectional optical wavelength demultiplexer. When light having a wavelength of $\lambda_{10}\text{-}\lambda_{17}$ is input to the first central waveguide 200 in the first waveguide array 202, and simultaneously light having a wavelength of $\lambda_{10}\text{-}\lambda_{17}$ is input to the second central waveguide 210 in the second waveguide array 212, the light having a wavelength of $\lambda_{10}\text{-}\lambda_{17}$ is output via the other waveguides in the second waveguide array 212, and the light having a wavelength of $\lambda_{10}\text{-}\lambda_{17}$ is output via the other waveguides in the first waveguide array 202. That is, when multiplexed light having several wavelengths is received via the central waveguide formed within each of the first and second arrayed waveguides, light received via the central waveguide within an arrayed waveguide is demultiplexed by wavelengths and output via a plurality of waveguides within an arrayed waveguide opposite to the arrayed waveguide which has received the multiplexed light.

[0019] To be more specific, when light having several wavelengths is received via the first central waveguide 200, the first planar waveguide region 204 distributes the received light, and the AWG 206 allows light beams from the first planar waveguide region 204 to have different phase differences. The second planar waveguide region 208 causes interference between light beams having different phase differences, which are output from the AWG 206, and outputs light beams of different wavelengths via different waveguides within the second waveguide array 212. Likewise, when light having several wavelengths is received via the second central waveguide 210, lights of different wavelengths are output via different waveguides within the first waveguide array 202.

[0020] When the central waveguide in the bidirectional optical wavelength multiplexer/demultiplexer according to the present invention is only used as an input waveguide, it is preferable that an optical isolator is connected to the input-dedicated waveguide in order to prevent interference or a return loss due to output light.

[0021] FIG. 5 illustrates an example in which a bidirectional optical wavelength multiplexer/demultiplexer according to the present invention operates as a bidirectional optical wavelength multiplexer. When light beams of different wavelengths $\lambda_{10}\text{-}\lambda_{17}$ are received by the waveguides (except for the first central waveguide 200) of the first waveguide array 202, they are multiplexed and output via the second central waveguide 210. Likewise, when light beams of different wavelengths $\lambda_{10}\text{-}\lambda_{17}$ are received by the waveguides (except for the second central waveguide 210) of the second waveguide array 212, they are multiplexed and output via the first central waveguide 200.

[0022] FIG. 6 illustrates an example in which a unidirectional optical wavelength multiplexer/demultiplexer according to the present invention operates as a bidirectional optical wavelength demultiplexer. When light having different wavelengths $\lambda_{10}\text{-}\lambda_{17}$ is received by the first central waveguide 200 of the first waveguide array 202, and light beams of different wavelengths $\lambda_{10}\text{-}\lambda_{17}$ are received by the remaining waveguides, the light beams of different wavelengths $\lambda_{10}\text{-}\lambda_{17}$ are multiplexed and output via the second central waveguide 210, and the multiplexed light having different wavelengths $\lambda_{10}\text{-}\lambda_{17}$ is demultiplexed and output via the waveguides (except for the second central waveguide 210) of the second waveguide array 212.

[0023] It is preferable that an output waveguide is selectively connected to an optical fiber in a packaging step in order for this bidirectional optical wavelength multiplexer/demultiplexer to have different channel intervals in two directions. The configuration or designing variables of a conventional optical wavelength multiplexer/demultiplexer can be used as those of the device in a chip step.

Industrial Applicability

[0024] As described above, according to an optical wavelength multiplexer/demultiplexer according to the present invention, a central waveguide, through which multiplexed light is received and output, is added together with a plurality of optical waveguides, at a place where the output spectrum of these waveguides are not affected, so that the multiplexed light can be demultiplexed in a direction from an optical waveguide array on one side to an optical waveguide array on the other side, and simultaneously demultiplexed light can be multiplexed in a direction opposite to the above direction.

Claims

1. An optical wavelength multiplexer/demultiplexer including an optical waveguide array having a plurality of optical waveguides, a planar waveguide region connected to the optical waveguide array, and an arrayed waveguide grating connected to the planar waveguide region, wherein the optical waveguide array further comprises a central waveguide formed at a location on which light transmitted from the arrayed waveguide grating to the planar waveguide region is focused, on the interface between the optical waveguide array and the planar waveguide region, and light multiplexed with a plurality of wavelengths is received or output via the central waveguide.

2. The optical wavelength multiplexer/demultiplexer of claim 1, wherein an optical isolator for preventing an interference or return loss due to output light is further connected to the central waveguide.

3. The optical wavelength multiplexer/demultiplexer of claim 1, further comprising:

a second planar waveguide region connected to the arrayed waveguide grating; and
a second optical waveguide array connected to the second planar waveguide region,
wherein the second optical waveguide array further comprises a second central waveguide formed at a location on which light transmitted from the arrayed waveguide grating to the second planar waveguide region is focused, on the interface between the second optical waveguide array and the second planar waveguide region, and light multiplexed with a plurality of wavelengths is received or output via the second central waveguide.

4. An optical wavelength multiplexer/demultiplexer including a first optical waveguide array, a first planar waveguide region connected to the first optical waveguide array, an arrayed waveguide grating connected to the first planar waveguide region, a second planar waveguide region connected to the arrayed waveguide grating, and a second optical waveguide array connected to the second planar waveguide region, the device characterized in that the first optical waveguide array comprises:

an input-dedicated waveguide formed at a location on which light transmitted from the arrayed waveguide grating to the planar waveguide region is focused, on the interface between the first optical waveguide array and the planar waveguide region; and
a plurality of output-dedicated waveguides for outputting light beams of a plurality of wavelengths, respectively, the second optical waveguide array comprises:

an input-dedicated waveguide formed at a location on which light transmitted from the arrayed waveguide grating to the planar waveguide region is focused, on the interface between the second optical waveguide array and the planar waveguide region; and
a plurality of output-dedicated waveguides for outputting light beams of a plurality of wavelengths, respectively,

wherein a first light beam multiplexed with a plurality of wavelengths is received via the input-dedicated waveguide of the first optical waveguide array, and light beams of wavelengths obtained by demultiplexing the first multiplexed input light beam are output via the plurality of output-dedicated waveguides in the second optical waveguide array, and a second light beam multiplexed with a plurality of wavelengths is received via the input-dedicated waveguide of the second optical waveguide array, and light beams of wavelengths obtained by demultiplexing the second multiplexed input light beam are output via the plurality of output-dedicated waveguides in the first optical waveguide array.

5. The optical wavelength multiplexer/demultiplexer of claim 1, wherein an optical isolator for preventing an interference or return loss due to output light is further connected to the input-dedicated waveguide in the first or second optical waveguide array.

6. An optical wavelength multiplexer/demultiplexer including a first optical waveguide array, a first planar waveguide region connected to the first optical waveguide array, an arrayed waveguide grating connected to the first planar waveguide region, a second planar waveguide region connected to the arrayed waveguide grating, and a second optical waveguide array connected to the second planar waveguide region, the device characterized in that the first optical waveguide array comprises:

an output-dedicated waveguide formed at a location on which light transmitted from the arrayed waveguide grating to the planar waveguide region is focused, on the interface between the first optical waveguide array and the planar waveguide region; and
a plurality of input-dedicated waveguides for receiving light beams of a plurality of wavelengths, respectively, the second optical waveguide array comprises:

an output-dedicated waveguide formed at a location on which light transmitted from the arrayed waveguide grating to the planar waveguide region is focused, on the interface between the second optical waveguide array and the planar waveguide region; and
a plurality of output-dedicated waveguides for outputting light beams of a plurality of wavelengths, respectively,

wherein light beams of wavelengths are received via the plurality of input-dedicated waveguides in the second optical waveguide array, respectively, and multiplexed light obtained by multiplexing the input light beams of a plurality of wavelengths is output via the output-dedicated waveguide in the first optical waveguide array, and

light beams of wavelengths are received via the plurality of input-dedicated waveguides in the first optical waveguide array, respectively, and multiplexed light obtained by multiplexing the input light beams of a plurality of wavelengths is output via the output-dedicated waveguide in the second optical waveguide array.

- 5 7. An optical wavelength multiplexer/demultiplexer including a first optical waveguide array, a first planar waveguide region connected to the first optical waveguide array, an arrayed waveguide grating connected to the first planar waveguide region, a second planar waveguide region connected to the arrayed waveguide grating, and a second optical waveguide array connected to the second planar waveguide region, the device characterized in that the first optical waveguide array comprises:
- 10 a first central waveguide for receiving light multiplexed with a plurality of wavelengths, the first central waveguide formed at a location on which light transmitted from the arrayed waveguide grating to the planar waveguide region is focused, on the interface between the first optical waveguide array and the planar waveguide region; and
- 15 a plurality of input-dedicated waveguides for receiving light beams of a plurality of wavelengths, respectively, the second optical waveguide array comprises:
- 20 a second central waveguide for outputting multiplexed light obtained by multiplexing light beams received via the plurality of input-dedicated waveguides, the second central waveguide formed at a location on which light transmitted from the arrayed waveguide grating to the planar waveguide region is focused, on the interface between the second optical waveguide array and the planar waveguide region; and
- 25 a plurality of output-dedicated waveguides for demultiplexing the multiplexed light received via the first central waveguide in the first optical waveguide array, according to wavelength, and outputting the demultiplexed light beams of a plurality of wavelengths.
8. The optical wavelength multiplexer/demultiplexer of claim 7, wherein an optical isolator for preventing an interference or return loss due to output light is further connected to the first central waveguide.

FIG. 1

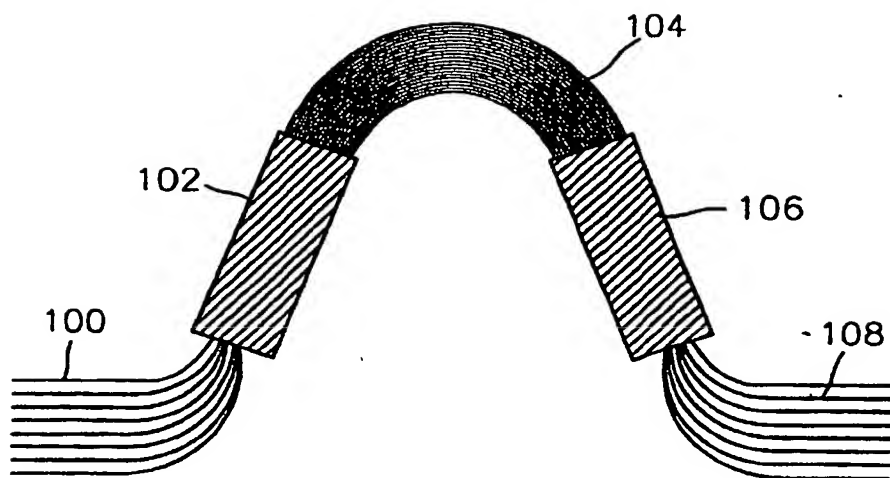


FIG. 2

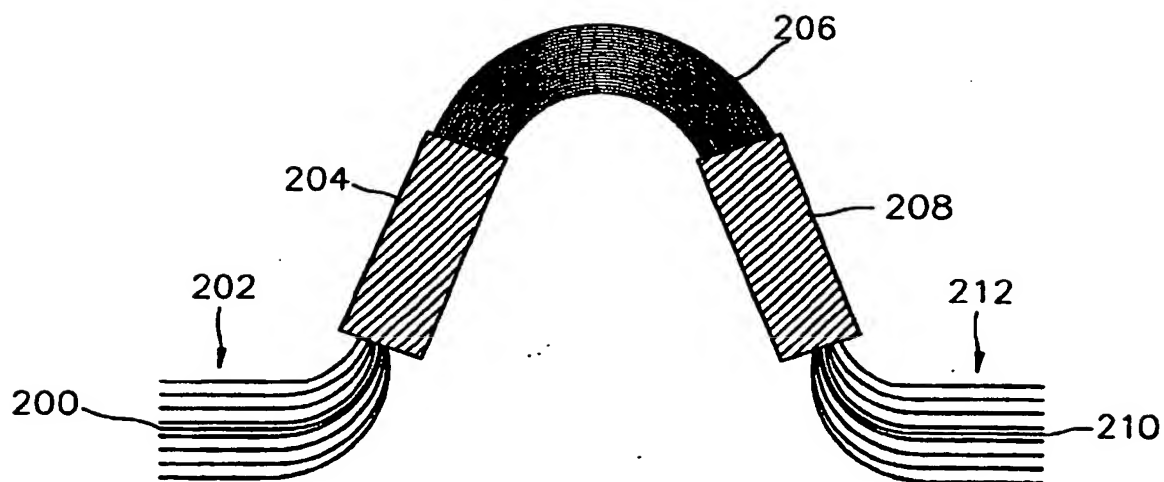


FIG. 3

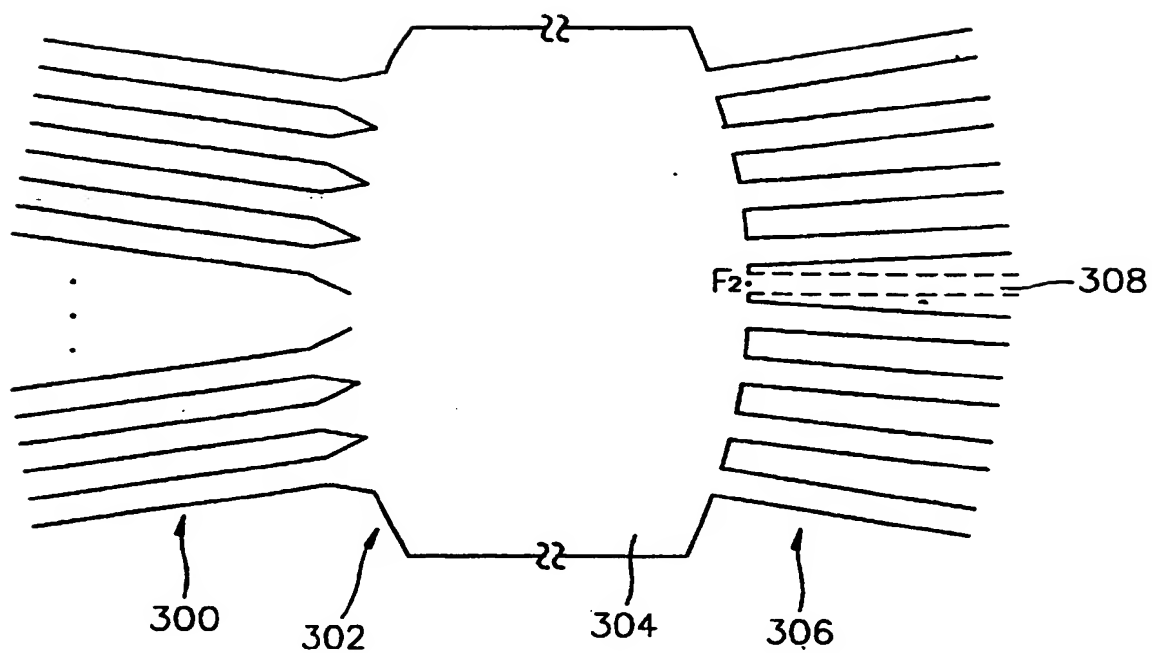


FIG. 4



FIG. 5

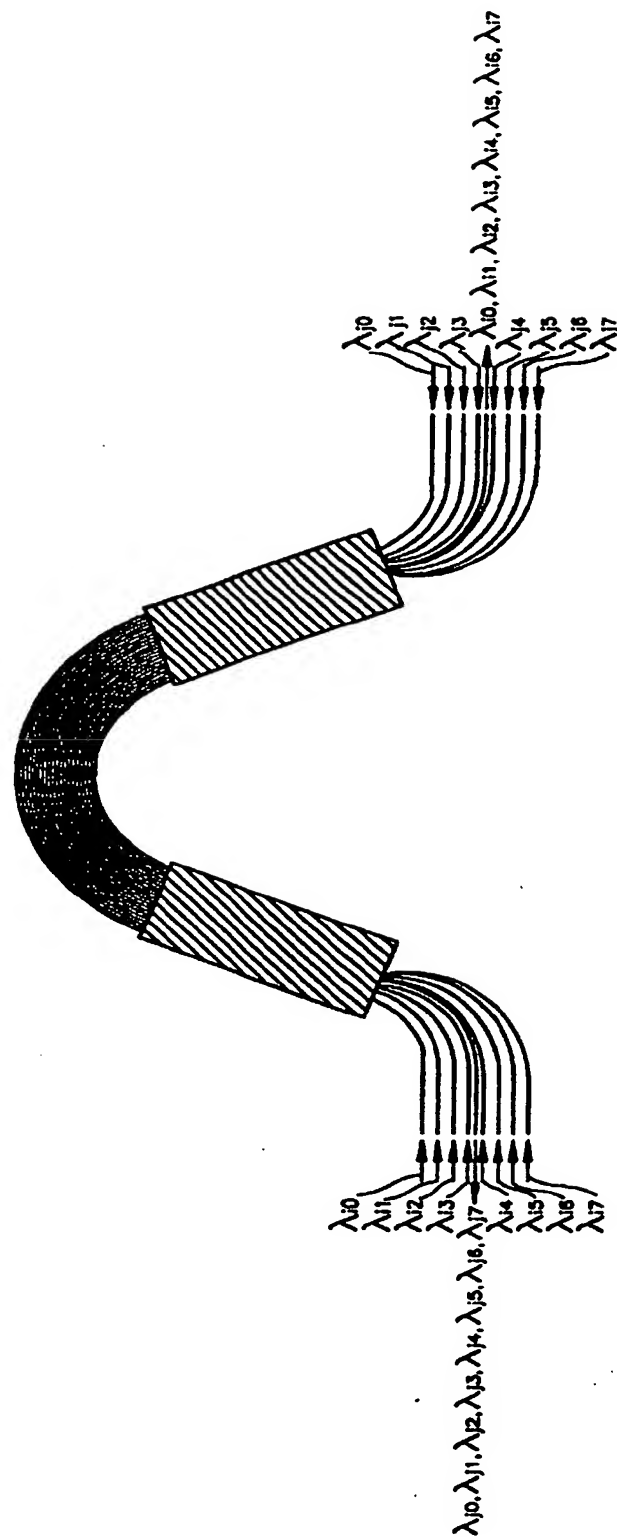
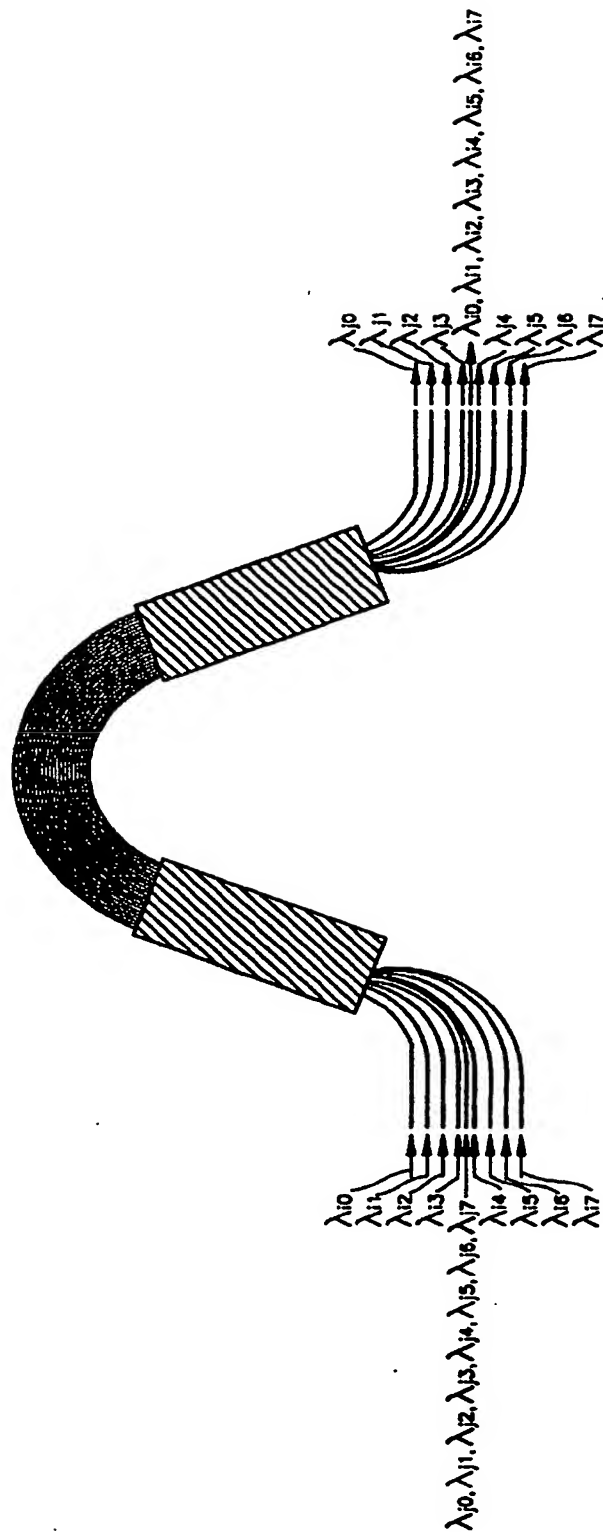


FIG. 6



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR99/00191A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl.⁶ G02B6/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl.⁶ G02B6/12-6/14Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1926-1996 Toroku Jitsuyo Shinan Koho 1994-1999
Kokai Jitsuyo Shinan Koho 1971-1999 Jitsuyo Shinan Toroku Koho 1996-1999

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP, 9-49936, A (Hitachi Cable, Ltd.), 18 February, 1997 (18. 02. 97) (Family: none)	1, 3 2, 4-8
X A	JP, 1-44901, A (Polaroid Corp.), 17 February, 1989 (17. 02. 89) & US, 4786131, A & EP, 301194, A	1 2-8
A	JP, 2665114, B2 (AT&T Corp.), 20 June, 1997 (20. 06. 97) & US, 5136671, A & EP, 528652, A	3-8

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search
10 August, 1999 (10. 08. 99)Date of mailing of the international search report
17 August, 1999 (17. 08. 99)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)

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VIA FACSIMILE and DHL

June 17, 2004

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GWA

CONFIRMATION

Re: US Patent Application for:

WAVELENGTH DIVISION MULTIPLEXER/DEMULTIPLEXER

Based on KPA No: 2002-73406; KPA Filing Date: November 25, 2002

Serial No. : 10/607,466

Filed : June 26, 2003

Your Ref. : P10660-US/ST/ysi

Our Ref. : 5000-1-376

Dear Mr. Rhee,

As you instructed, we have filed the response to the pending Office Action and a copy of the Certified Translation of the Priority Document. An invoice and a copy of the response filed with the U.S. Patent and Trademark Office is enclosed herein.

As always, thank you for entrusting this matter, and we will promptly notify of any further action from the patent office.

If you have any question, please contact the undersigned.

Sincerely Yours,

CHA & REITER

By: 
Steve Cha

SC/lc

Enclosures (w/confirmation copy)